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Ammonia as a Marine Fuel

2024
NOVEMBER, NEW ORLEANS

PREPARED FOR
Ammonia Energy Association Annual Conference

Ammonia as a Marine Fuel - Agenda

- Introduction
- Regulatory Drivers
- No/Low Carbon Fuels: Pros & Cons
- Meeting the Scale Challenge
- Conclusions

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Poten's Suite of Services

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Founded 1938 and part of BGC Group since 2018

Sectors: Crude Oil, Refined Products, Asphalt, LNG, LPG, Hydrogen, Ammonia & Methanol

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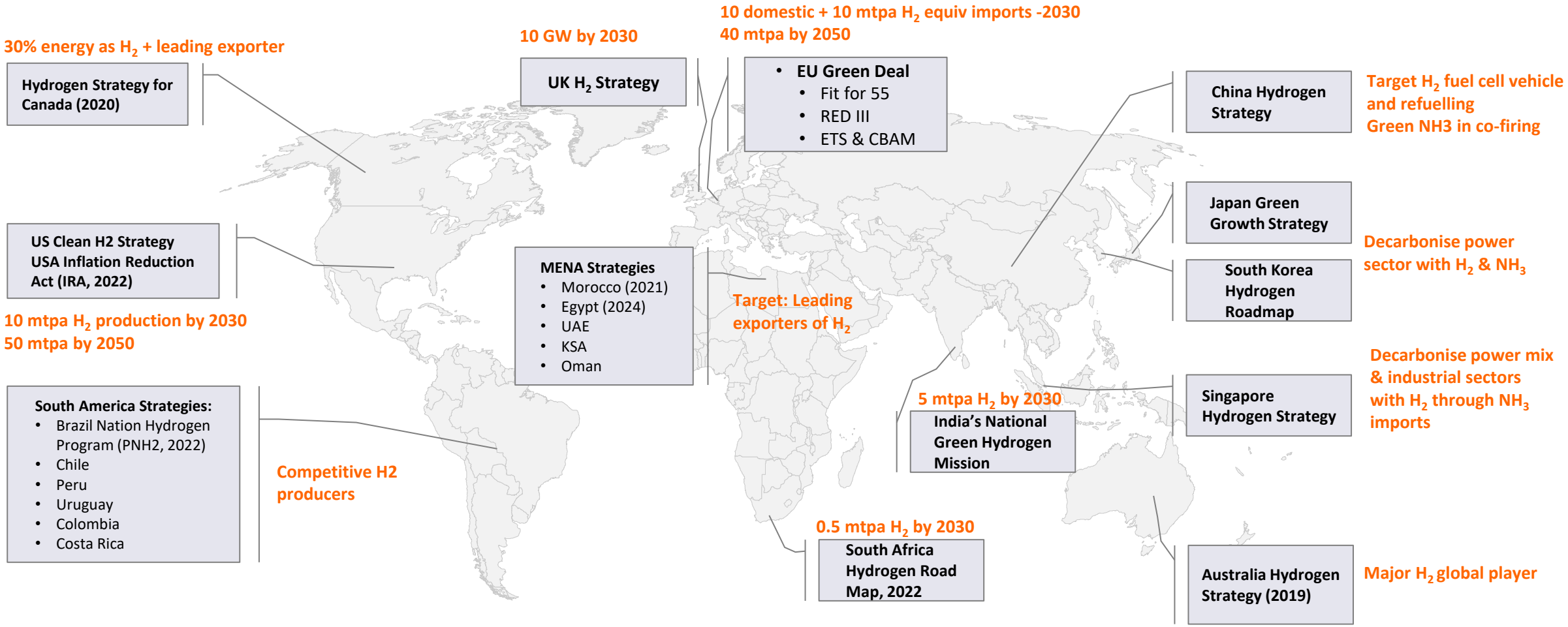
Poten Hydrogen, Ammonia and Methanol Advisory Services

MARKETS & PROFITABILITY	• Market dynamics (supply/demand/trade) projections for zero/low carbon fuels • Profitability and pricing forecasts • Delivered cost competitiveness & market entry strategy
TECHNICAL SUPPORT	• Independent technology evaluation • Asset reviews • Feasibility studies for hydrogen, ammonia and methanol supply chains
SHIPPING	• Clean fuel trade routes; technical and commercial shipping challenges/opportunities • Ship engine progress and maturity needed for marine fuels adoption • Marine fuel environmental solutions
COMMERCIAL & STRATEGIC	• Project commercial structure and risk management • Offtake contract key terms • Conducting procurement or sales tenders
INDEPENDENT 3rd PARTY ADVISOR	• Project finance Lenders' Independent Advisor (Technical, EHS&S, Market, Shipping) • Private equity and Investors/Divestors due diligence support • Expert Witness/Litigation Support

Clients include operators/owners, lenders, investors, shipping companies and Governments

The better environmental impact and development of climate policies encouraging hydrogen will also be driving the adoption of H_2-derived fuels (e.g. ammonia etc)



Most regions and countries have developed national hydrogen strategies led by Western Europe and North East Asia

International shipping accounts for 3% of GHG emissions; IMO has introduced short-, mid- and long-term measures

FuelEU Maritime has also set goals, but IMO targets global shipping

IMO : 2023 Strategy on Reduction of GHG Emissions from Ships Replaces 2018 strategy

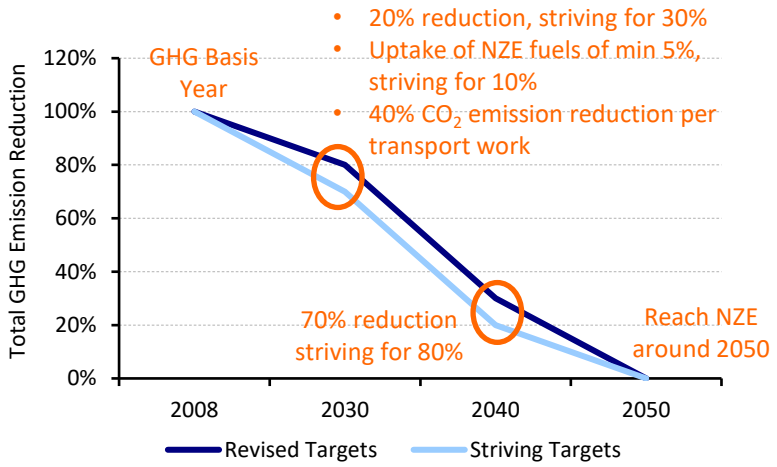
Objective: Total GHG reduction and uptake of low- / zero-carbon fuels in the marine sector
Target: International Shipowners
Scope: Individual vessel rating system used to drive allowable emissions

EU : 2024 EU ETS extended to cover CO_2 emissions from all large ships entering EU ports

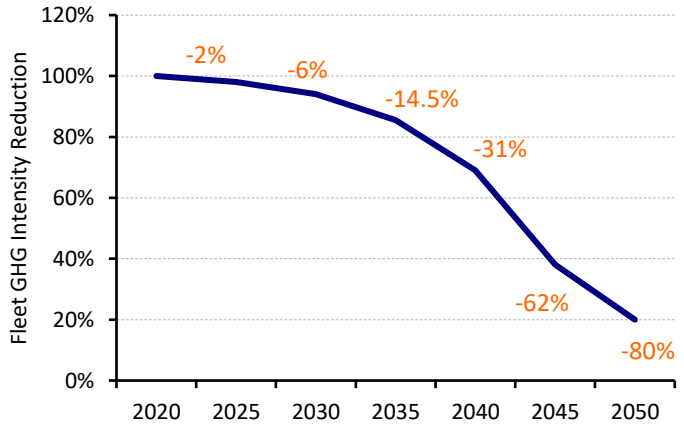
Target: Shipowners with fleets operating in EU
Scope: Tank to Wake Basis; EUA purchase to cover yearly emissions

EU : 2023 FuelEU Maritime

Objective: GHG intensity reduction via eligible alternative fuels from 2025
Target: Shipowners with fleets operating in the EU
Scope: Well to Wake Basis. FuelEU penalties

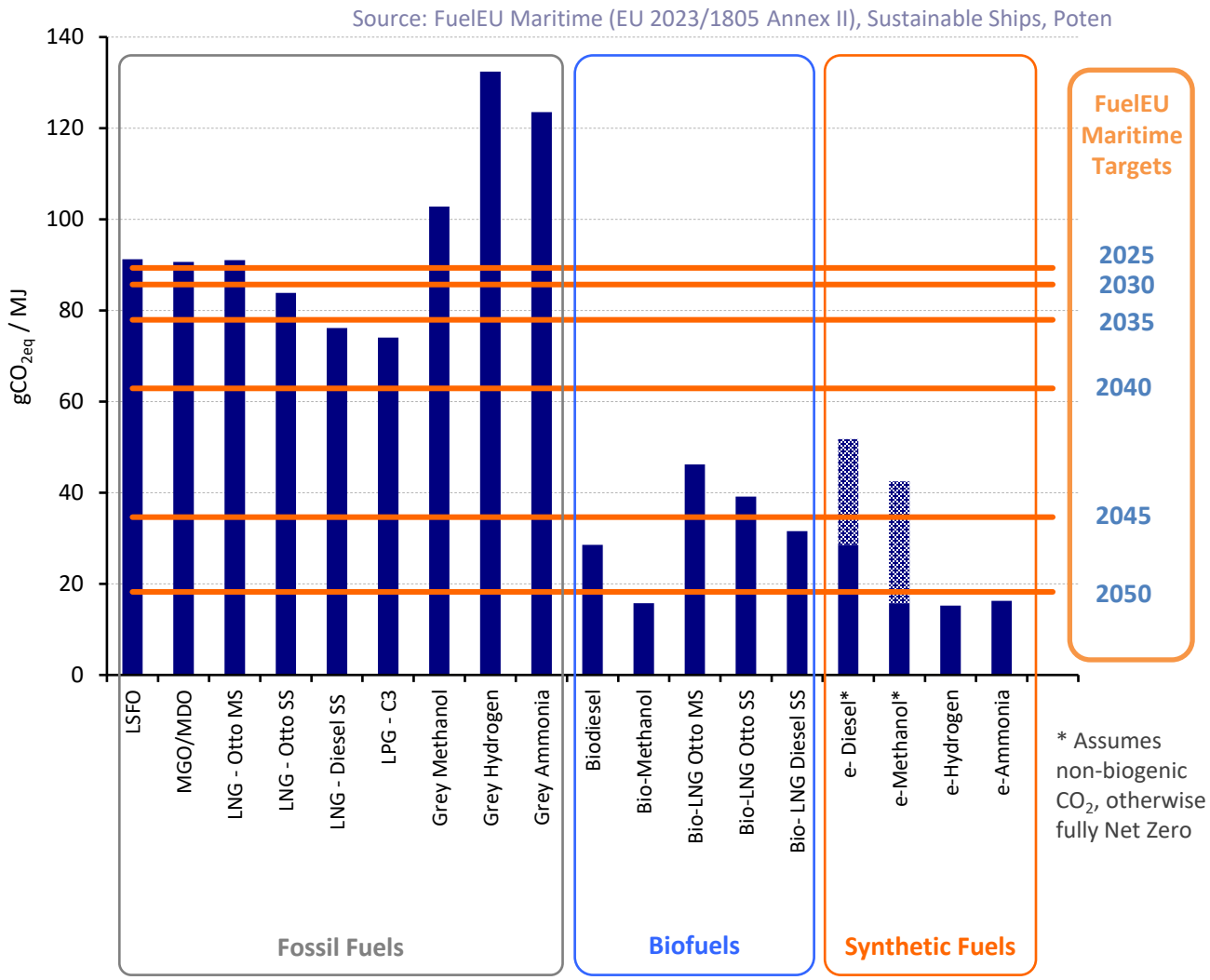


- Cargo's origin matters:
  - 100% allowance if loaded/ discharged within EU, 50% otherwise
- Phase in of EUAs to cover emissions
  - 2024: 40%
  - 2025: 70%
  - 2026: 100% + CH_4 & N_2O emissions included



FuelEU Maritime is part of Fit for 55 legislation and aims to increase demand and use of low carbon fuels to achieve NZE

Marine Fuel Carbon Intensity (WtW) & FuelEU Timeline



- FuelEU Maritime incorporates:
  - Voluntary pooling mechanism for ships operated across a fleet
  - Borrowing/banking on an individual ship basis
  - Shore power or NZE technology mandatory for container and passenger ships from 2030
- Eligible fuels
  - Fossil fuels with GHG intensity < 91.2 gCO_{2eq}/MJ – 2020 basis
  - Synthetic and Recycled Carbon Fuels (RFNBO and RCF) some Biofuels (RED II/III)
  - 2 x multiplier benefit for using RFNBO until 2034, 2% RFNBO mandated after 2034
- Baseline reductions allow use of LNG/LPG fuel until 2039 - longer with banking prior to 2039 and even longer if mix of bio-LNG is also used
- After 2041, non-biogenic CO_2 can no longer be used in e-fuels manufacture
  - e-diesel & e-MeOH (from fossil CO_2 origin) can no longer be used without restriction or blending with less intensive fuels
  - Biogenic CO_2 may restrict future e-MeOH marine fuel supply as this is also required for SAF

All new fuels face challenges and Poten expects multiple fuels to be adopted to meet specific needs

Alternative Marine Fuels Challenges

	Fuel Oil	Bio-diesel	LNG	LPG	eMeOH	e-NH_3	e-LH_2
Safety							
Flammability							
Explosion Risk							
Toxicity/handling							
Marine Fuel Readiness							
Engine (ICE)							
Training /regulations							
Infrastructure (bunkering)							
Economic Attractiveness							
Supply pathway maturity							
Proven Scale							
Raw Material Availability							
Relative cost							

Source: Poten

- Biodiesel and bio-LNG - easy “drop-in” replacements but face feedstock supply and cost challenges – cannot supply entire marine fuel needs
- Methanol fuelled ships already in operation and growing…but:
  - e-MeOH is more capital intensive with requirement to capture & supply CO2 feed
  - Biogenic CO2 availability is limited and direct air capture (DAC) development is uncertain/very expensive
- Ammonia – can meet post-2050 requirements but faces near-term supply and handling challenges
  - Step-change training required to handle safely
  - Engine test applications - future commercial orders placed and interim marine fuel guidelines developed
- H2 can meet post-2050 requirements but faces substantial cost and handling challenges; engine testing ongoing & pre-interim marine fuel guidelines developed

Scale: we will need significantly more ships and larger fuel quantities to move the energy transition fuels

Physical Properties of Alternative Fuels vs LSFO

				Alternative Fuels versus LSFO	
	Storage Temp	Density	Energy (LHV)	Energy content Ratio	# Ships to deliver same energy cargo
	°C	(kg/m^3)	(MJ/kg)		
LSFO	Ambient	951	41.6	1.0	1.0
MDO	Ambient	845	44.0	0.9	1.1
Biodiesel	Ambient	875	37.3	1.1	1.2
LPG	-42	537	46.6	0.9	1.6
LNG	-162	458	48.6	0.9	1.8
Methanol	Ambient	786	19.9	2.1	2.5
Ammonia	-33	682	18.6	2.2	3.1
LH_2	-253	71	120.2	0.3	4.6

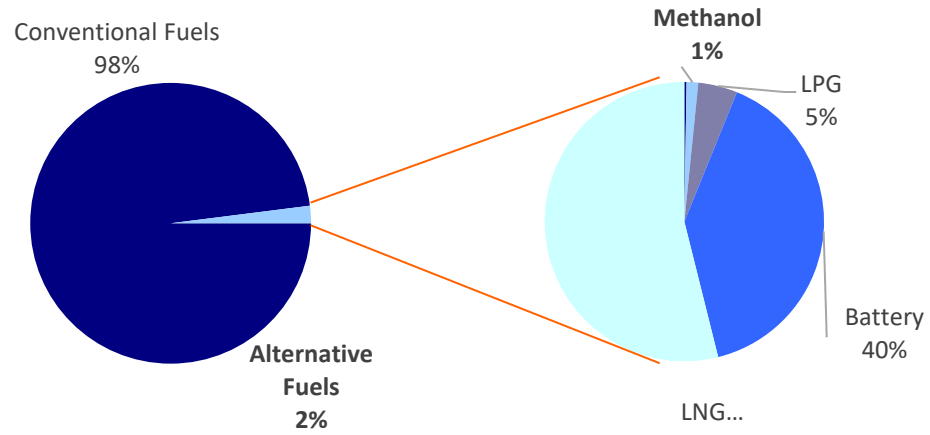
Source: Poten

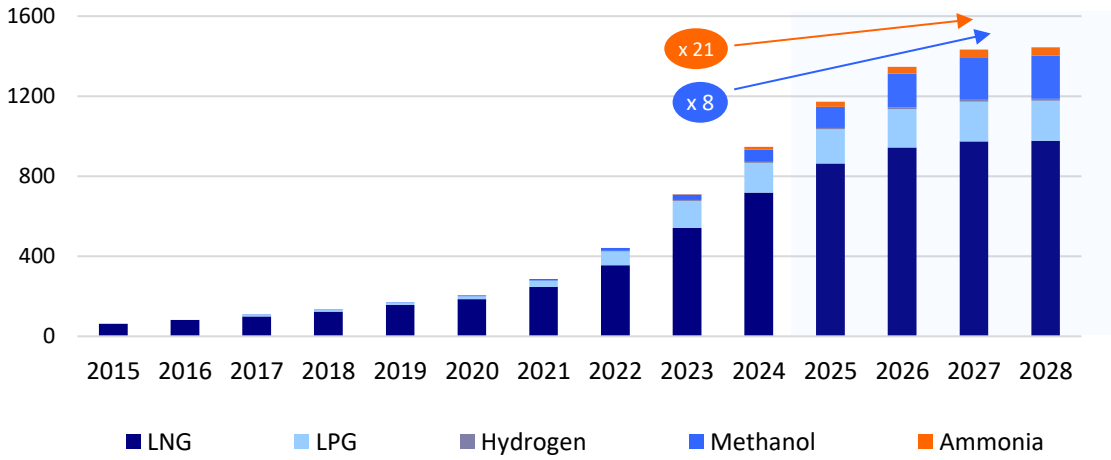
- We will need to carry significantly more alternative fuels to get the same amount of energy moving around – 50+ VLAC's on order!
- Full decarbonisation by 2050 requires about 270 mtpa of fuel oil equivalent of clean fuels (~600 mtpa ammonia equivalent!)
- Marine sector will need to compete with other sectors' demand for low carbon ammonia (power and ammonia cracking for H2)
- World-scale ammonia capacity currently ~1 mtpa so we will need a lot of new plants as well as new ships!
- Ammonia already traded as cargo but additional requirements relating to safe bunkering, storage and use

Alternative Marine Fuels – Current Trends

- LNG marine fuel has seen strongest growth plus some LPG
- Stronger future near-term methanol growth
  - 27 methanol fuelled ships currently in use & 216 in the order book for delivery 2024-2027;
  - Concern that renewable methanol supplies may restrict uptake
- Ammonia marine engines tested - by 2025
  - Expected as main marine fuel in use by 2050 to achieve NZE
  - First orders of ammonia “ready” and dual fuelled ~33 by 2026
  - Handling and wider acceptance challenges remain
- Onboard CCS being evaluated to extend use of fossil fuels but faces major cost/technical challenges

Ships In Operation





Source: DNV, Poten

Key Take Aways – Ammonia as a Marine Fuel

- Climate regulatory changes will drive the adoption of low carbon intensity marine fuels
- There will be a phased reduction in allowable emissions but by 2050 only renewable methanol, ammonia (and H2) can achieve the requirements from a baseline perspective
- We will need significantly more ships and larger fuel quantities to move the energy transition fuels due to energy content and density differences
- Shipping industry expected to use range of fuels to replace staple fossil fuels:
  - Fossil fuels: no longer unrestricted use without blending with lower carbon intensity fuels or onboard carbon capture (which has significant cost/technical challenges)
  - LNG, LPG and bio-diesel/bio-LNG will have significant transitory roles to play
  - Stronger methanol uptake in the near-medium term but biogenic CO2 may restrict future e-MeOH post-2041 as this is also required for SAF production
  - Ammonia and LH2 fuels contain zero carbon (but LH2 appears unviable for deep-sea)
  - Ammonia anticipated to become major marine fuel by 2050 to meet climate goals but has near-term challenges to overcome

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